JLCEdu (Journal of Learning and Character Education)
PISSN: 2776-1215 EISSN: 2776-1207
Volume: 5 Number: 1 pp. 41-47, May 2025
https://sra.yhmm.or.id/index.php/JLCEdu

CRITICAL THINKING IN THE DIGITAL ERA: THE STRATEGIC ROLE OF COMPUTATIONAL THINKING IN HIGHER EDUCATION

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Abstract

This study aims to examine the strategic role of Computational Thinking (CT) in strengthening university students' critical thinking skills in the digital era. CT is understood as a systematic thinking approach that includes decomposition, pattern recognition, abstraction, and algorithms for solving complex problems. The research employed a descriptive qualitative method, with data collected through in-depth interviews, classroom observations, and document analysis. Participants consisted of lecturers and students from a public university that has implemented CT-based learning strategies. The findings indicate that CT contributes positively to enhancing students' critical thinking abilities, particularly in problem analysis, logical argument construction, information evaluation, and decision-making. CT is most effective when applied through collaborative and project-based learning, supported by clear instructional design. Challenges include limited CT literacy among non-technical students and insufficient lecturer preparedness. The study recommends curriculum development and pedagogical training to support interdisciplinary CT integration in higher education.

Keywords: Computational Thinking, critical thinking, higher education, collaborative learning, digital curriculum

I. INTRODUCTION

The 21st century is marked by rapid changes driven by advances in digital technology, artificial intelligence, and automation. These changes have affected not only the industrial and economic sectors but have also fundamentally transformed how people learn, work, and interact. The Future of Jobs Report released by the World Economic Forum (2023) projects that as many as 85 million jobs will be replaced by machines, while around 97 million new jobs will be created that demand 21st-century skills, including critical thinking, complex problem-solving, as well as digital and technological literacy. This context indicates that the main challenge for education is to prepare human resources, especially university students, to survive, adapt, and compete amidst the rapid technological disruption. One form of such preparedness lies in students' ability to think critically and systematically. However, critical thinking alone is not enough. In a digital era filled with complexity and data, a thinking approach is needed that can organize information, break down major problems into smaller parts, and construct logical and executable solutions. This is what is known as Computational Thinking (CT). The term was first introduced by Seymour Papert in the 1980s and was later popularized by Jeannette Wing in 2006, who defined it as a way of thinking to solve problems, design systems, and understand human behavior by referring to the basic concepts of computer science.

CT encompasses four main pillars, namely decomposition (the ability to break down big problems into smaller, more understandable parts), pattern recognition (the ability to identify similarities across various problems), abstraction (the ability to filter important information and ignore irrelevant details), and algorithms (the ability to arrange logical steps to solve problems). These four pillars are not only relevant in the world of computer science or engineering, but are also highly useful in everyday life and various fields of study. With CT, students are expected to face real-world challenges more logically, structurally, and efficiently. Recent studies show that CT contributes significantly to improving students' critical thinking skills. For example, research by Yadav et al. (2021) found that CT-based training had a positive impact on enhancing students' critical thinking and creativity. Similar results were also shown in a study by Lee and Kang (2022), which examined the impact of integrating CT into AI-based visual learning and found significant improvements in analytical and problem-solving skills. Meanwhile, research by Chen et al. (2023) concluded that CT combined with metacognitive training in collaborative programming environments effectively improved student learning outcomes and reflective abilities.

In the context of Indonesian higher education, the development of CT still faces several challenges. Although the Ministry of Education, Culture, Research, and Technology has begun encouraging the integration of digital literacy into the curriculum, CT has not yet been explicitly made a core component in developing students' skills across study programs. Data from the World Bank (2022) shows that Indonesia still has a low score in terms of the digital skill index compared to other Southeast Asian countries. One of the causes is the still limited application of pedagogical approaches that cultivate higher-order thinking skills in higher education environments. This illustrates the urgency to review existing teaching methods so they can better equip students with thinking skills that match the demands of the times. Higher education holds a strategic position in building critical thinking skills. Paul and Elder (2006) define critical thinking as an active and disciplined intellectual process directed at conceptualizing, applying, analyzing, synthesizing, and evaluating information gathered from experience, observation, reflection, reasoning, or communication as a basis for action. In this context, CT can be positioned as a complementary approach that strengthens the critical thinking structure of students. A study conducted by Liu et al. (2021) revealed that CT strengthens the analytical and evaluative dimensions that are at the core of critical thinking in cross-disciplinary learning activities.

More recent research by Khine et al. (2022) in the context of STEAM and CT integration shows that students experienced significant improvements in problem analysis, strategy development, and the generation of creative solutions. These findings are reinforced by a systematic review by Shute et al. (2021), which states that CT can serve as a foundation for the development of higher-order thinking skills needed in various academic and professional fields. Even the most recent study by Chan et al. (2025) highlights the potential of generative AI based on language (such as ChatGPT) in building students' CT in a more interactive and contextual way. However, there has been little research that specifically examines the strategic role of CT in strengthening students' critical thinking in Indonesian higher education. Most studies are still limited to coding instruction or the implementation of information technology. In fact, if CT is functioned more conceptually and across disciplines, its potential influence on the development of students' intellectual capacity would be far greater. Amidst the flood of information, hoaxes, and the challenges of complex data analysis, the ability of students to think critically based on CT becomes increasingly vital. Based on this background, this study aims to explore and analyze the strategic role of CT in strengthening students' critical thinking skills in the digital era. The focus of this study will be directed at a conceptual review of CT, an examination of its integration into higher education learning, the identification of challenges and implementation barriers, and the formulation of practical recommendations for higher education policy development. It is hoped that the results of this research can make a real contribution to the improvement of learning strategies that are relevant, adaptive, and responsive to future competency needs.

II. RESEARCH METHOD

This study employs a descriptive qualitative approach to provide an in-depth depiction of the strategic role of Computational Thinking (CT) in strengthening university students' critical thinking skills in the digital era. This approach was chosen as it is well-suited to exploring complex and contextual phenomena from the perspective of participants. The descriptive design allows the researcher to describe how CT is implemented in learning and how it influences students' thinking processes (Miles, Huberman, & Saldaña, 2020). Data collection was carried out through in-depth interviews, classroom observations, and document analysis such as Semester Learning Plans (RPS) and student project assignments. Informants were selected using purposive sampling techniques, involving lecturers and students from various study programs who have been engaged in the application of CT in the classroom. The validity of the data was reinforced through source and method triangulation, as well as member checking to ensure the accuracy of the collected data (Creswell & Poth, 2021).

The data were analyzed using thematic analysis, which involved transcription, data reduction, coding, and the identification of key themes related to the implementation of CT and the enhancement of critical thinking. To ensure the trustworthiness of the findings, the study refers to four criteria: credibility, transferability, dependability, and confirmability (Nowell et al., 2017). The research process was conducted in accordance with research ethics principles, such as informed consent, anonymity, and the use of data solely for academic purposes.

III. DISCUSSION

This study aims to describe how Computational Thinking (CT) plays a role in strengthening university students' critical thinking skills in the digital era. Based on data analysis obtained through observations, in-depth interviews, and documentation, several key findings were identified that illustrate the relationship between the application of CT and the improvement of students' quality of thinking in higher education. One major finding shows that students' and lecturers' understanding of CT has continued to develop, even though not all come from technological or informatics backgrounds. Lecturers generally understand CT as a systematic thinking approach that can be applied in learning to solve problems in a structured way. This approach is applied through problem-based learning, case studies, and project-based methods. Meanwhile, students, although initially unfamiliar with the term or framework of CT, gradually began to understand the concept through learning activities designed to be collaborative and contextual.

The application of CT in the classroom varies depending on the characteristics of the course and each lecturer's teaching approach. Some lecturers integrate CT explicitly in learning plans and classroom activities, such as guiding students to break down problems into smaller parts, recognize patterns from similar cases, filter essential information, and construct logical and targeted steps for solutions. This approach enables students to develop systematic thinking skills that influence how they understand and solve both academic and practical problems. The impact of CT on students' critical thinking skills can be observed in several aspects. First, students become more capable of distinguishing between relevant and irrelevant information when completing tasks or projects. Second, they demonstrate improved abilities in constructing logical arguments, identifying cause-and-effect relationships, and making decisions based on systematic analysis. Third, students become more active in discussions, more reflective of their own thinking processes, and more confident in presenting academically sound solutions. In other words, CT provides a thinking framework that strengthens logical structure and analytical depth in students' learning processes. However, this study also found that not all students or lecturers share the same level of understanding about CT. Students from non-engineering programs generally require more time to adapt to the thinking patterns offered by this approach. They tend to be accustomed to learning models oriented toward memorization and single answers, making the CT approach—which demands exploration and multi-perspective analysis—a challenge. Nevertheless, after going through several project-based or case-based learning cycles, their ability to think critically and systematically improved significantly.

From the lecturers' perspective, the biggest challenge is how to design learning activities that not only deliver content but also encourage students to think deeply and structurally. Some lecturers admitted they had not received specific training on CT and its implementation in non-computational curricula. As a result, although they are aware of the importance of CT, not all lecturers are able to design learning processes that explicitly develop this capability in students. This indicates that strengthening lecturers' capacity is a key factor in the successful integration of CT in higher education. Another finding shows that learning strategies involving CT are more effective when supported by collaborative approaches, active learning, and the use of relevant technology. Students involved in group projects, case-based discussions, and reflective assignments demonstrated improvement in their thinking, both in terms of logic and creativity. Additionally, integrating CT into assessments—such as open-ended tasks, portfolios, and argument-based presentations—also encouraged students to develop more critical and structured ways of thinking.

The study also shows that learning documents such as Semester Learning Plans (RPS) and lecture modules play an important role in supporting CT implementation. When CT principles are explicitly included in learning objectives and teaching strategies, students find it easier to understand learning expectations and align their thinking with the CT framework. Conversely, in courses that do not explicitly include this approach, students tend to experience difficulties adjusting to the thinking patterns required in tasks or projects. To clarify CT's contribution to enhancing students' critical thinking skills, this study compiles quantitative data based on observations of four key aspects of critical thinking. These aspects include the ability to analyze problems, construct arguments, evaluate information, and make logical decisions. The assessments were conducted before and after the implementation of CT-based learning through document analysis of assignments, classroom activities, and student reflections. The results are presented in Table 1 below:

Table 1. Table 1. Improvement in Critical Thinking Skills

Aspect of Critical Thinking Skills	Before CT (%)	After CT (%)	Improvement (%)
Problem Analysis	60	82	22
Argument Construction	55	85	30
Information Evaluation	50	80	30
Decision Making	58	83	25

The data in the table above shows a consistent improvement across all aspects of students' critical thinking skills after the implementation of CT-based learning. The highest increases occurred in the aspects of argument construction and information evaluation, each experiencing a 30% jump. This indicates that CT is capable of encouraging students not only to understand a concept but also to assess and reconstruct it into logical and in-depth arguments. This change demonstrates that CT functions not only as a technical approach but also as a cognitive strategy that strengthens the foundation of critical thinking across disciplines.

Overall, the findings of this study indicate that Computational Thinking (CT) serves as a bridge between conceptual understanding and the application of critical thinking skills at the higher education level. CT not only encourages students to solve problems but also helps them develop a systematic, analytical, and adaptive way of thinking in response to contemporary challenges. Its consistent and well-planned implementation is capable of creating a learning environment that emphasizes not only cognitive achievement but also the comprehensive strengthening of students' thinking processes. The results of the study show that CT has a significant impact on improving university students' critical thinking skills. Students involved in CT-based learning demonstrate better abilities in identifying the core of a problem, constructing logical arguments, filtering relevant information, and formulating solutions based on systematic thinking processes. These findings are consistent with research by Yadav et al. (2021), which emphasizes that integrating CT into learning not only enhances programming or technical skills but also strengthens students' critical thinking and creativity across various fields of study. The application of CT in learning processes enables students to become familiar with structured thinking procedures, from problem decomposition to formulating algorithm-based solutions. In the context of higher education, this approach has proven to ease students' efforts in managing complex materials and academic tasks. Lee and Kang (2022), in their study on CT implementation in a visual AI course, concluded that students who used the CT approach in completing assignments exhibited higher analytical performance and were more reflective in decision-making. This aligns with the findings of the current study, where students showed a tendency to think more structurally, critically, and deeply after participating in CT-based learning.

Additionally, this study confirms that CT can be effectively applied across disciplines, including in the fields of education and social sciences. This supports the findings of Khine et al. (2022), who investigated the impact of CT integration in STEAM education and found that the approach not only improved technical skills but also developed critical and creative thinking in non-technical contexts. In this study, students from education and social science programs—who were previously unfamiliar with CT—also showed improvements in constructing arguments, analyzing cases, and evaluating solutions more objectively and rationally. However, the study also reveals that not all students and lecturers possess an equal level of understanding and skill in applying CT. This challenge is echoed in the literature review by Shute et al. (2021), which states that although the benefits of CT are widely recognized, many higher education institutions still lack structured strategies to fully integrate it into the curriculum. This issue arises due to limited training for educators and a lack of concrete guidelines on how to apply CT across different disciplines. Furthermore, the study emphasizes the importance of making the CT approach explicit in learning plans, such as in Semester Learning Plans (RPS) and course modules. When this approach is explicitly written in learning documents, students better understand the expected ways of thinking and can more easily develop appropriate problem-solving strategies. This reinforces the findings by Chen et al. (2023), who stated that the implementation of CT becomes more effective when accompanied by clear instructional design that supports student reflection throughout the learning process.

From the perspective of strengthening critical thinking skills, this study shows that Computational Thinking (CT) helps students develop various dimensions of critical thinking, such as analysis, synthesis, evaluation, and reflection. This is consistent with the framework developed by Paul and Elder (2006), which states that critical thinking includes the ability to evaluate information objectively and make decisions based on sound reasoning. In this study, students engaged in CT-based activities showed a stronger tendency to evaluate arguments, assess the validity of information, and draw conclusions based on evidence. In addition to quantitative results and field findings, it is important to understand how CT can be systematically integrated into the higher education curriculum. Based on document analysis and interviews with lecturers, a pattern of phases was identified as necessary for ensuring that CT integration can be optimal and sustainable. This pattern is summarized in the following flow diagram:

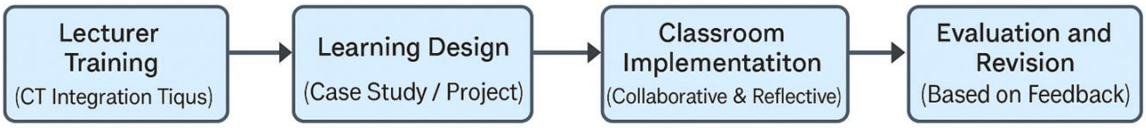

Figure 1. Flow Diagram of CT Integration in Higher Education Curriculum

The diagram illustrates a structured flow for integrating Computational Thinking (CT) into higher education curricula. It begins with curriculum planning, involving the development of course documents such as the RPS (Semester Learning Plan) and syllabus to ensure that CT principles are clearly outlined from the start. This is followed by lecturer training, where educators are equipped with techniques to integrate CT into their teaching practices effectively. Training at this stage is essential to ensure that lecturers across various disciplines understand and are able to apply CT concepts, even if they are not from computer science backgrounds. Next, the process moves to learning design, which emphasizes the use of case studies and project-based learning to contextualize CT for students. This is followed by classroom implementation, where the designed activities are applied using collaborative and reflective methods to engage students actively in structured problem-solving. The final stage, evaluation and revision, focuses on collecting feedback and assessing learning outcomes to improve future instructional strategies. This cyclical model ensures that CT integration is not only systematic and sustainable but also aligned with students' needs and evolving digital-era competencies.

IV. CONCLUSSION

This study aims to describe the strategic role of Computational Thinking (CT) in strengthening university students' critical thinking skills in the digital era. Based on data analysis through observation, in-depth interviews, documentation, and analysis of learning documents, several key conclusions. CT has been proven to significantly contribute to the development of students' critical thinking skills. Through the application of CT principles such as decomposition, pattern recognition, abstraction, and algorithmic thinking, students demonstrated improvements in problem analysis, logical argument construction, information evaluation, and data-based decision making. The implementation of CT in learning is effective when delivered through collaborative, project-based, and contextual approaches. Students became more active, reflective, and confident in their thinking processes, and were able to develop logical and structured problem-solving strategies. Lecturers play a vital role in the successful integration of CT into learning. However, gaps still exist in lecturers' understanding and skills in designing and implementing CT, especially outside the fields of computer science or engineering. This highlights the need for training and educator capacity building. Challenges in implementing CT include the lack of explicit CT principles in learning documents, limited CT literacy among students from non-technical disciplines, and the uneven application of CT-based learning strategies across academic programs. Therefore, systematic strategies and institutional support are necessary for sustainable integration. To support the effective implementation of CT, higher education institutions need to develop curriculum guidelines that explicitly incorporate CT, conduct pedagogical training for lecturers, and encourage the use of assessment models that emphasize higher-order thinking skills. As a direction for future development, this study recommends conducting further research using quantitative or mixed-method approaches to measure the long-term and cross-institutional impact of CT implementation on learning outcomes. In addition, it is also important to develop CT-based learning models that are adaptive to the characteristics of different academic programs, so that the benefits can be more widely experienced by the entire academic community.

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